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The Effectiveness of Foreign Exchange Intervention in Australia: A Factor Model Approach with GARCH Specifications

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Abstract

This paper analyses the effectiveness of foreign exchange intervention by the Reserve Bank of Australia (RBA). Initially, a latent factor model is used to decompose the volatility of exchange rates into three unobserved factors - world, numeraire and idiosyncratic. Subsequently, the impact of foreign exchange rate intervention is examined by further decomposing the numeraire (Australian) factor into an intervention component and an unobserved component. An *indirect estimation* approach is employed to facilitate the imposition of GARCH structures on some of the unobserved factors. The empirical results suggest that less than three percent of observed exchange rate volatility is explained by RBA intervention.

Key words: exchange rate, latent factor model, indirect estimation
JEL Classification: C22, F31, G15

1. Introduction

Foreign exchange intervention by central banks is potentially important as a means of calming volatile and disorderly markets - reversing the impact of excessive exchange rate depreciation or appreciation, and minimizing the repercussions of unexpected monetary policy changes (Rankin, 1998). Since the managed floating of the Australian dollar in December 1983, official intervention by the Reserve Bank of Australia (RBA) has received much attention by economic researchers and academics. However, two decades on, economic researchers still lack conclusive evidence regarding the effectiveness of foreign exchange intervention. While some have argued that intervention by the RBA has been pointless and ineffective (Juttner and Tonkin, 1992), others have supported the efforts made by the Reserve Bank in stabilizing the Australian dollar exchange rate (Lim and Harper, 1991; Blundell-Wignall and Fahrer, 1993; Andrew and Broadbent, 1994; Karunaratne, 1995; 1996; Kim, Kortian and Sheen, 2000; Kearns and Rigobon, 2002).[1]

Previous studies of exchange rate intervention have used models incorporating exchange rate risk premium (Andrew and Broadbent, 1994), exponential GARCH specifications (Kim, Kortian and

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[1] Many studies have examined the effectiveness of foreign exchange intervention by Central Banks in other countries, for example, Glick and Hutchison (1994), Baillie and Osterberg (1997), Dominguez (1998) and Aguilar and Nydahl (2000).

Sheen, 1999) and optimal control model (Karunaratne, 1995) to examine the effectiveness of intervention. The primary objective of this paper is to quantify the contribution of foreign exchange rate intervention using an alternative approach, namely, a latent factor model of exchange rates.[2] This model allows the volatility of exchange rates to be decomposed into three unobserved factors - world, numeraire and idiosyncratic. The model also allows the imposition of the commonly observed GARCH characteristics of exchange rates into the model. In particular, GARCH specifications are imposed on the variances of some of the significant unobserved factors. The unobserved nature of the factors provides insufficient information to identify the parameters using simple regression techniques. Therefore, the model is estimated using a procedure known as *indirect estimation* (Gourieroux, Montfort and Renault, 1993). The impact of foreign exchange rate intervention is examined by further decomposing the numeraire (Australian) factor into an intervention component and an unobserved component.

In this analysis, four bilateral exchange rates - the US dollar, Deutsche mark, Japanese yen and Canadian dollar - against a common numeraire (the Australian dollar) are considered. This paper examines different periods of intervention activity based on the tenures of the different governors of the RBA. Since the floating of the dollar in December 1983, the RBA has had three governors, beginning with R.A. Johnston, who held his position until 18 July 1989. B.W. Fraser took over the position until 17 September 1996 and the present governor, I.J. Macfarlane, took up the position on 18 September 1996.

The organisation of this paper is as follows: Section 2 specifies the latent factor model of exchange rates and incorporates the observed variable, namely, the net purchases of foreign exchange intervention, into the latent factor model; Section 3 outlines the indirect estimation technique; Section 4 provides a description of the data; Section 5 reports the empirical results and Section 6 provides some concluding remarks.

2. Model Specification

Section 2.1 describes the latent factor model of exchange rates and section 2.2 incorporates the role of foreign exchange intervention into the latent factor model.

2.1 A Factor Model of Exchange Rate Volatility with GARCH Specifications

In this section, a latent factor model of exchange rates analogous to Dungey (1997) is specified.[3] The model assumes that a bilateral exchange rate is determined by three independent unobserved factors, a world factor, a numeraire factor and an idiosyncratic factor.[4] Letting $s_{i0,t}$ be the bilateral exchange rate between country *i* and the numeraire country at time *t*

[2] The latent factor model is a generalisation of the factor model developed by Mahieu and Schotman (1994) analogous to Dungey (1997, 1999).

[3] The origin of this model is the multi-factor model proposed by Mahieu and Schotman (1994) which relies on restrictions imposed on the covariance matrix for identification. By the imposition of the arbitrage condition, Dungey (1999) proposed an alternative approach, extending Mahieu and Schotmans' model to a estimable three-factor model.

[4] Aigner, Hsiao, Kapteyn and Wansbeek (1992) noted that the definition of a latent variable requires its independence, a fact often overlooked in comments on this type of model.

$$s_{i0,t} = \lambda_i F_{w,t} + \phi_i F_{i,t} + \phi_0 F_{0,t} \qquad \text{where } i = 1,2,3\ldots,n \qquad (1)$$

where F_w is the world factor, F_i is the idiosyncratic factor associated with country i and F_0 is the factor associated with a numeraire country, λ_i, ϕ_i and ϕ_0 are response coefficients associated with the various factors and n is the number of bilateral exchange rates used in the system. The model assumes that the common world factor affects each exchange rate differently, the common numeraire factor affects exchange rates equally and the idiosyncratic factors represent events originating from the non-numeraire countries.

The variances of each of the factors are assumed to equal one, that is, var(F) = I. Note that, if this assumption is violated, the parameter estimates will absorb the variance of the unobserved factors. Therefore, comparing the factor coefficients will not yield much information. For this reason, the ratios of the contribution of the factors to the volatility of the exchange rates are examined. In this case, the true value of the variance does not have any effect on the results.

Following Diebold and Nerlove (1989), Mahieu and Schotman (1994) and Dungey Martin and Pagan (2000), each of the factors are specified to follow a GARCH(1,1) process.[5]

$$F_{k,t} = \rho_k F_{k,t-1} + u_{k,t} \qquad \textit{for } k=i,w,0, \qquad i=1,2,\ldots.,n \qquad (2)$$

where

$$u_{k,t} = \sqrt{h_{k,t}}\, e_{k,t} \qquad (3)$$

$$h_{k,t} = 1 - \alpha_k - \beta_k + \alpha_k u_{k,t-1}^2 + \beta_k h_{k,t-1} \qquad (4)$$

$$e_{k,t} \sim N(0,1)$$

where ρ_k are the AR(1) parameters and $k = n + 2$ factors. The restriction $(1 - \alpha_k - \beta_k)$ normalises the unconditional variance of the factors to be one.[6] Under this specification, the factor contributions to the volatility of exchange rates are defined as follows:

Numeraire factor $$\frac{\phi_0^2/(1-\rho_0^2)}{\text{var}(s_{i0})} \qquad (5)$$

Idiosyncratic factor $$\frac{\phi_i^2/(1-\rho_i^2)}{\text{var}(s_{i0})} \qquad (6)$$

World factor $$\frac{\lambda_i^2/(1-\rho_w^2)}{\text{var}(s_{i0})} \qquad (7)$$

In this paper, a system of four bilateral exchange rates, the US dollar ($S_{USD/AUD}$), Deutsche mark ($S_{DEM/AUD}$), Japanese yen ($S_{YEN/AUD}$) and Canadian dollar ($S_{CAD/AUD}$) against the common numeraire,

[5] Mahieu and Schotman's factor model of exchange rates assumes that the covariances between each of the exchange rates and a common numeraire are equal and positive (Dungey, 1997).

[6] See Diebold and Nerlove (1989).

the Australian dollar (*AUD*) is examined. In a system of four bilateral exchange rates, there will be four idiosyncratic factor coefficients (f_i), four world factor coefficients (l_i), one common numeraire factor coefficient (f_0), six coefficients from the AR(1) process in equation (2) (r_k), six GARCH parameters (a_k) and six ARCH parameters (b_k). Overall, in a system of four bilateral exchange rates, 27 parameters in the model need to be estimated.

2.2 Role of Foreign Exchange Intervention in the Factor model

In this section, the volatility of exchange rates is decomposed even further to examine the impact of an observed factor of determination. Specifically, the factor relating to the numeraire currency is decomposed into two components - an unobserved factor and an observed variable. As stated earlier, the observed variable incorporated into the factor model is foreign exchange intervention by the RBA.

In order to incorporate the intervention variable into the model, the unobserved numeraire factor from equation (1) is decomposed. That is, the Australian factor is taken to be the summation of the observed variable (intervention) and the remaining unobserved factors associated with the Australian dollar.

$$\phi_0 F_{0,\mathrm{t}} = \phi_{UNOB} F_{UNOB,t} + \phi_{INT} F_{INT,t} \tag{8}$$

where F_{UNOB} is the unobserved component of the factor associated with the numeraire country, Australia, and F_{INT} is the observed component, which is the intervention by the RBA. Substituting equation (8) into (1) gives

$$s_{i0,t} = \lambda_i F_{\mathrm{w,t}} + \phi_i F_{i,t} + \phi_{UNOB} F_{UNOB,t} + \phi_{INT} F_{INT,t} \tag{9}$$

Section 3 explains how λ_i and ϕ_i are obtained. To calculate the other coefficients in the model, the variance of $\phi_0 F_0$ from equation (8) is taken to give

$$\phi_0^2 \mathrm{var}(F_0) = \phi_{UNOB}^2 \mathrm{var}(F_{UNOB,t}) + \phi_{INT}^2 \mathrm{var}(F_{INT,t}) \tag{10}$$

where cov($F_{INT,t}$, $F_{UNOB,t}$) = 0 by assumption. Given that the variance of the unobserved factors, var(F) = I, equation (10) reduces to

$$\phi_0^2 = \phi_{UNOB}^2 + \phi_{INT}^2 \mathrm{var}(\mathrm{F}_{INT,t}) \tag{11}$$

where ϕ_0^2 can be obtained using *indirect estimation* as described in section 3, var($\mathrm{F}_{INT,t}$) can be obtained from the data and ϕ_{INT}^2 and ϕ_{UNOB}^2 are the unknown coefficients. The unknown coefficients can be estimated using the following simple regression:

$$s_{i0,t} = \delta_{i0} + \phi_{i0,INT} F_{INT,t} \tag{12}$$

The contribution of intervention (ϕ_{INT}) may be different for each bilateral exchange rate. Therefore, to find the common impact of intervention, ϕ_{INT} is restricted to the same value across all exchange rates using the following restriction matrix R:

$$R = \begin{bmatrix} 0 & 1 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 \end{bmatrix}$$

Rewriting the n simple regressions given by equation (12) using matrix algebra as

$$e = Xk \tag{13}$$

where e is an $nT \times 1$ vector of exchange rate returns, and X is an $nT \times 2n$ matrix of ones and factor values with zeros added to ensure conformability with k, which is a $2n \times 1$ vector of the parameters. The common impact of intervention is the value in any even row of the following vector:

$$k^* = k - (X'X)^{-1}R'[R(X'X)^{-1}'R']Rk \tag{14}$$

Subsequently, the common impact of intervention (ϕ_{INT}) is substituted into equation (11) to obtain ϕ_{UNOB}

3. Estimation Technique

To estimate the factor model of exchange rates with GARCH specifications, an estimation technique that allows the specification of further structures on the factors is employed. Specifically, the *indirect estimation* procedure as developed by Gourieroux et al. (1993) is adopted. *Indirect estimation* requires the use of an auxiliary model that mimics the properties of the true model. First, parameters of the auxiliary model are estimated using observed data. Subsequently, simulated data from the true model is used to obtain alternative parameter estimates of the auxiliary model. Then the parameter estimates of the true model are matched by the dynamic properties of the auxiliary model for simulated data and observed data.

Let F be the vector of all unknown parameters in the true theoretical model in equations (1), (2), (3) and (4) to be estimated. A set of auxiliary equations must be specified. Further, the appropriate auxiliary model must have similar characteristics to the true model. Here the chosen auxiliary model is a VAR(1) in levels of the exchange rates and squares of the residuals as described below.

The factors with the AR(1) process are represented by the following VAR(1) model of the bilateral exchange rates

$$s_t = As_{t-1} + u_t \tag{15}$$

where s_t and s_{t-1} are $n \times 1$ vectors of exchange rate returns, A is an $n \times n$ matrix of parameters, and u_t is an $n \times 1$ vector of error terms. In this paper, since four bilateral exchange rates are considered, s_t can be defined as

$$s_t = \begin{bmatrix} s_{USD/AUD,t} \\ s_{DEM/AUD,t} \\ s_{JPY/AUD,t} \\ s_{CAD/AUD,t} \end{bmatrix}$$

The volatility of exchange rates is characterised by the second moments, that is, var($s_{i0,t}$) and cov($s_{i0,t}$, $s_{j0,t}$), where j ≠ i. The auxiliary model of the GARCH specifications in equations (3) and (4) is a VAR(1) model of the squared errors of equation (15). That is,

$$u_t^2 = C + Du_{t-1}^2 + e_t \tag{16}$$

where u_t^2 and u_{t-1}^2 are $n \times 1$ vectors of squared errors, C is an $n \times 1$ vector of constant terms, D is an $n \times n$ matrix of parameters, and e_t is an $n \times 1$ vector of error terms. Overall, there are $n(n + 1)/2$ moments, n^2 parameters from equation (15) and $n + n^2$ parameters from equation (16). Hence, for a system of n bilateral exchange rates, there are $(5n^2 + 3n)/2$ parameters in the auxiliary models.

Let B be a vector of parameters of the auxiliary model from equations (15) and (16). The aim is to estimate F, a vector of parameters from the true model. The initial step of the indirect estimation process is to estimate the auxiliary model using observed data and obtain a vector of estimates $\hat{B}$. Note that since the true model is more complicated than the auxiliary model, only B is estimated using observed data. The second step is to choose a value of F, say F_o, then simulate $s_{i0,t}$ for i = *USD*, *DEM*, *CAD* and *JAP*, under the true model specifications given in equations (1), (2), (3) and (4) with the error term generated as N(0,1). Then, using the simulated data, estimate the auxiliary model to obtain $\tilde{B}$. This simulation is repeated H times, then the average value of $\tilde{B}_h$ obtained. The final step is to calibrate the parameters such that the difference between the auxiliary model parameter estimates using observed data and those using simulated data is minimised. That is, to minimise the distance between $\hat{B}$ and the average $\tilde{B}_h$ using the following objective function:

$$\text{Min } \Phi \ (\hat{B} - \sum_{h=1}^{H} \tilde{B}_h / H)' \Theta^{-1} (\hat{B} - \sum_{h=1}^{H} \tilde{B}_h / H)$$

where Θ is a weighting matrix. A form of this weighting matrix is given by Gourieroux, Monfort and Renault (1993). The weighting matrix used in the *indirect estimation* is given as

$$\Theta = 1/[(g'g + (1-L/(M + 1))*(W + W'))/p]$$

where

L is the number of lags (L = 4)[7]
M is the maximum number of lags (M = 4)
p is the number of parameters in the auxiliary model
W = $g_t'g_{t-1}$ where g is the T x p matrix contained in the right hand side of the auxiliary model (T is the number of observations).

From the auxiliary models, there will be 10 moment conditions, 16 parameters from equation (15) and 20 parameters from equation (16). There are 46 parameters in the auxiliary model while there are only 27 parameters in the true model; hence the model is overidentified.

4. Data Description

Daily exchange rate series are obtained from Datastream over the period 12-12-83 to 8-5-00. Bilateral exchange rates against the Australian dollar (*AUD*) used in estimation are the US dollar ($S_{USD/AUD}$), the Deutsche mark ($S_{DEM/AUD}$), the Japanese yen ($S_{YEN/AUD}$) and the Canadian dollar ($S_{CAD/AUD}$). The choice of exchange rates are based on the triennial foreign exchange surveys conducted by BIS (1999), which show that these currencies were within the world's top ten by turnover. The exchange rate series in logs are presented in Figures 1 to 4. An 'eye ball' test indicates that the movements in the US dollar and the Canadian dollar have been similar. The Japanese yen and the Deutsche mark moved in generally the same direction until 1990, diverging thereafter.

The intervention series is net foreign exchange purchases by the RBA, obtained from the RBA itself. The graphical representation of this series is given in Figure 5. Negative values represent purchases of foreign exchange and positive values represent sales of foreign exchange. This intervention series is not a clean intervention series, as it also includes purchases and sales by the RBA on behalf of the Government. However, this series has been used commonly to represent intervention in previous studies (for example, Andrew and Broadbent, 1994). Figure 5 indicates that foreign exchange intervention supported the Australian dollar in three distinct phases. Firstly, between July 1986 and October 1987 when the Australian dollar was highly volatile. According to Rankin (1998), intervention during this period was used to signal the market. Secondly, between 1991 and 1993, and finally during the Asian crisis in late 1997 and early 1998, which are consistent with Rankin (1998). It is also evident from Figure 5 that sales of the Australian dollar were implemented more often and in small amounts, while purchases were less frequent but in larger amounts.

The exchange rate series and intervention data are used to estimate the multi-factor model over the post-float period. The data is subdivided according to the terms held by the various governors at the RBA - the R.A. Johnston (RAJ) period (12-12-83 to 18-7-89), the B.W. Fraser (BWF) period (18-9-89 to 17-9-96) and the I.J. MacFarlane (IJM) period (18-9-96 to 8-5-00)[8]. These sub-sample periods are considered to analyse whether or not the policies adopted by the various Governors influenced the results.

[7] We chose the maximum number of lags to be 4. Dungey et al. (2000) found that varying the number of lags did not make much difference to their results.

[8] Although this is the IJM period, the sample period used in the estimation begins at 1-6-95 to avoid small sample problems.

4.1 GARCH Characteristics of the Australian Dollar Exchange Rate

It is well known that financial market data follow a GARCH process.[9] Therefore, ARCH and GARCH properties of the daily Australian dollar exchange rates are examined over the three sample periods. Table 1 reports the estimates of the GARCH (1,1) model for the four bilateral exchange rates. α and β are the coefficients of the first order GARCH term. The corresponding standard errors are in parentheses. The results indicate significant first order GARCH effects for all exchange rates considered in this study.

During the RAJ period, the GARCH parameter estimates for all four currencies are around 0.12 and 0.80 respectively. Over the BWF period, the GARCH parameters are approximately 0.05 and 0.85 respectively. Similarly, for the IJM period, the GARCH parameters are about 0.05 and 0.90 respectively. Since the parameter estimates are similar, it is not necessary to enforce GARCH specifications on each of the idiosyncratic factors of equation (1). Instead, the specifications on the world factor will encompass the GARCH characteristics of the data. This specification is consistent with the results in Kose, Otrok and Whitemans (1999) and Dungey, Martin and Pagan (2000).

5. Empirical Results

Section 5.1 reports the results from the application of *indirect estimation* and section 5.2 examines the role of foreign exchange intervention in the Australian currency market.

5.1 Empirical Estimates of the Factor Model of Exchange Rate Volatility with GARCH Specifications

As discussed in Section 3, incorporating the GARCH properties of the Australian dollar exchange rates into the three-factor model requires the use of *indirect estimation*. The parameter estimates for equations (1) and (4) using *indirect estimation* are presented in Table 2.[10] Since the factor coefficients themselves are not informative, the proportion of variance of the exchange rates explained by each of the factors is calculated, and the results are reported in Table 3.

The results indicate that the Australian factor is dominant for $S_{USD/AUD}$ and $S_{CAD/AUD}$ across all periods. During the RAJ period, its contributions are dominant in all exchange rates, but over the BWF and the IJM periods, it is more important to the $S_{USD/AUD}$ and $S_{CAD/AUD}$ than the $S_{DEM/AUD}$ and $S_{JPY/AUD}$. The idiosyncratic factor becomes more important over time. Its contributions associated with $S_{USD/AUD}$ increased from 2.4% over the RAJ period to 9.1% and 9.3% over the BWF and IJM periods respectively. Similar increments are observed with its contributions associated with the other currencies. The idiosyncratic factor contribution associated with the $S_{JPY/AUD}$ is 64% for the IJM period. The world factor appears to play a minor role, excluding its importance for the $S_{DEM/AUD}$ across all periods. Its contributions associated with the $S_{USD/AUD}$ over the BWF and the IJM periods are less than 2%. Although its contributions associated with the Canadian dollar during the BWF period is 25%, during the IJM period it is as low as 1.5%.

[9] See Bollerslev, Chou and Kroner (1992).
[10] GMM estimates are used as starting values.

5.2 Role of Foreign Exchange Intervention

This section examines the effect of foreign exchange intervention by the RBA on the volatility of the Australian dollar exchange rates using the methodology described in Section 2.2. Refer to Table 4 for the parameter estimates on the intervention against each of the four bilateral exchange rates (vector k in equation (13)).

In this analysis, the OLS parameter estimates reported in Table 4 are used to calculate the proportion of variance explained by the observed intervention factor and the results are presented in Table 5. Note that these results are the same as those in Table 3 except that the domestic factor has been decomposed even further into an unobserved component and an intervention component. The results suggest that the proportion of the domestic factor contribution that is explained by intervention is 2.29% for the RAJ period. The volatility of exchange rates explained by the intervention factor associated with all four currencies is between 1.4% and 2%.

For the subsequent BWF period, the proportion of domestically contributed factor explained by the intervention factor is only 1.12%. Hence, there is a fall in the intervention factor contributions associated with $S_{DEM/AUD}$ and $S_{JPY/AUD}$ and a corresponding fall in the Australian factor contributions. The proportion of variance of $S_{USD/AUD}$ and $S_{CAD/AUD}$ attributable to intervention fell from 1.8% to 1%, despite the rise in the total domestic factor contributions. During the IJM period, the proportion of the domestically contributed factor explained by the intervention component is 0.19%. The proportion of variances of all four currencies attributable to intervention has decreased over time. For example, the intervention factor associated with $S_{USD/AUD}$ is down from 1.84% to 0.17%.

6. Conclusion

This paper used a latent factor model of exchange rates to decompose the volatility of exchange rates into three unobserved factors - world, numeraire and idiosyncratic. Furthermore, since it has been commonly detected that financial time series exhibit conditional heteroscedasticity, GARCH specifications were imposed on the variance of some of the unobserved factors. Applying *indirect estimation* enabled the estimation of the latent factor model with GARCH specifications.

The model was estimated over three sub-sample periods, divided according to the tenure of various governors of the RBA over the post-float period. The results indicate that the Australian factor was dominant for the US dollar and the Canadian dollar for all three periods. The world factor had a minor role to play other than its contributions associated with the Deutsche mark. The idiosyncratic factor contributions were negligible over the earlier periods, however its contribution increased during the I.J. MacFarlane (IJM) period.
The results also indicate that the role of foreign exchange intervention by the Reserve Bank of Australia has been small but significant. The intervention factor contributions associated with all four currencies as a proportion of the domestic factor contribution fell over the three periods. There was a corresponding fall in the domestic factor contributions associated with the Deutsche mark and the Japanese yen. Despite the increase in the domestic factor contributions associated with the US dollar and the Canadian dollar, the intervention factor contributions fell between the R.A. Johnston (RAJ) and I.J. MacFarlane (IJM) periods.

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Table 1: Univariate GARCH Properties of the Australian Dollar Exchange Rates

		$S_{USD/AUD}$	$S_{CAN/AUD}$	$S_{DEM/AUD}$	$S_{YEN/AUD}$
RAJ period	a_k	0.114	0.128	0.146	0.147
(12-12-83 to 18-7-89)		(0.011)	(0.016)	(0.018)	(0.014)
	b_k	0.874	0.840	0.795	0.826
		(0.011)	(0.019)	(0.025)	(0.016)
BWF Period	a_k	0.065	0.086	0.041	0.079
(18-9-89 to 17-9-96)		(0.010)	(0.012)	(0.007)	(0.009)
	b_k	0.899	0.831	0.920	0.898
		(0.015)	(0.024)	(0.013)	(0.013)
IJM Period	a_k	0.031	0.039	0.086	0.057
(1-6-95 to 8-5-00)		(0.005)	(0.00)	(0.022)	(0.009)
	b_k	0.965	0.949	0.710	0.900
		(0.006)	(0.011)	(0.099)	(0.016)

Standard errors are given in parentheses.

Table 2: Estimate of the Bilateral Exchange Rate System with GARCH Specifications

		RAJ period (12-12-83 to 18-7-89)	BWF Period (18-9-89 to 17-9-96)	IJM Period (1-6-95 to 8-5-00)
World Factor	$S_{USD/AUD}$	-0.285	0.026	0.066
	$S_{DEM.AUD}$	0.382	0.487	0.377
	$S_{JPY/AUD}$	0.226	0.362	0.103
	$S_{CAN/AUD}$	-0.215	-0.003	-0.044
Numeraire Factor	S_{AUD}	-0.613	-0.434	0.481
Idiosyncratic Factor	$S_{USD/AUD}$	-0.102	0.137	-0.147
	$S_{DEM/AUD}$	0.280	0.517	0.359
	$S_{JPY/AUD}$	-0.295	0.450	0.645
	$S_{CAD/AUD}$	-0.225	0.234	0.229
b_k	World	0.112	0.194	0.000
	Numeraire	0.056	0.100	0.697
a_k	World	0.515	0.676	0.697
	Numeraire	0.688	0.814	0.714

Table 3: Proportions of the Exchange Rate Variation Explained by Various Factors

	World Factor	Australian Factor	Idiosyncratic Factor
RAJ Period			
$S_{USD/AUD}$	17.501	80.110	2.389
$S_{DEM/AUD}$	24.461	62.327	13.212
$S_{JPY/AUD}$	10.029	73.162	16.809
$S_{CAD/AUD}$	9.780	79.524	10.696
BWF Period			
$S_{USD/AUD}$	0.338	90.592	9.070
$S_{DEM/AUD}$	34.246	26.919	38.835
$S_{JPY/AUD}$	25.322	36.026	38.652
$S_{CAD/AUD}$	0.003	77.406	22.591
IJM Period			
$S_{USD/AUD}$	1.725	88.974	9.301
$S_{DEM/AUD}$	28.067	44.942	26.991
$S_{JPY/AUD}$	1.589	34.263	64.148
$S_{CAD/AUD}$	0.666	81.020	18.314

Note: Figures are expressed in percentages

Table 4: Latent Factor Model, Parameter Estimates of System (9) Including Foreign Exchange Intervention

Exchange Rate	Parameter	Efficient Parameter Estimates			
		Full Period	RAJ period	BWF Period	IJM Period
$S_{USD/AUD}$	δ	-0.0139	-0.0255	0.0011	-0.0171
		(0.0996)	(0.0199)	(0.0110)	(0.0173)
	f_{INT}	0.0007***	0.0011***	0.0007***	0.0001
		(0.0001)	(0.0002)	(0.0001)	(0.0003)
$S_{DEM/AUD}$	δ	-0.0193	-0.0539**	-0.0138	-0.0175
		(0.0133)	(0.0226)	(0.0206)	(0.0231)
	f_{INT}	0.0007***	0.0013***	0.0005**	0.0000
		(0.0002)	(0.0003)	(0.0002)	(0.0003)
$S_{JPY/AUD}$	δ	-0.0315**	-0.0626***	-0.0148	0.0053
		(0.0129)	(0.0211)	(0.0002)	(0.0259)
	f_{INT}	0.0007***	0.0012***	0.0005**	0.0002
		(0.0002)	(0.0003)	(0.0003)	(0.0004)
$S_{CAD/AUD}$	δ	-0.0091	-0.0274	0.0091	-0.0097
		(0.0097)	(0.0196)	(0.0120)	(0.0175)
	f_{INT}	0.0006***	0.0010***	0.0006***	0.0000
		(0.0001)	(0.0002)	(0.0002)	(0.0003)
Restricted system	f_{INT}	0.0007	0.0011	0.0006	0.00003

***, ** and * denote the significance at the 1, 5 and a 10 percent significance levels respectively. Standard errors are given in parentheses.

Table 5: Proportions of the Exchange Rate Variation Explained by Various Factors with Foreign Exchange Intervention

	World Factor	Australian Factor		Idiosyncratic Factor
		Unobserved	Intervention	
RAJ Period				
$S_{USD/AUD}$	17.501	78.268	1.842	2.389
$S_{DEM/AUD}$	24.461	60.894	1.433	13.212
$S_{JPY/AUD}$	10.029	71.480	1.682	16.809
$S_{CAD/AUD}$	9.780	77.696	1.828	10.696
BWF Period				
$S_{USD/AUD}$	0.338	89.574	1.018	9.070
$S_{DEM/AUD}$	34.246	26.617	0.302	38.835
$S_{JPY/AUD}$	25.322	35.622	0.405	38.652
$S_{CAD/AUD}$	0.003	76.536	0.870	22.591
IJM Period				
$S_{USD/AUD}$	1.725	88.698	0.171	9.301
$S_{DEM/AUD}$	28.067	44.803	0.086	26.991
$S_{JPY/AUD}$	1.589	34.157	0.066	64.148
$S_{CAD/AUD}$	0.666	80.865	0.155	18.314

Note: Figures are expressed in percentages

Figure 1: The US dollar against the Australia Dollar Exchange Rate

$S_{USD/AUD}$

Figure 2: The Canadian Dollar against the Australian Dollar Exchange Rate

$S_{CAN/AUD}$

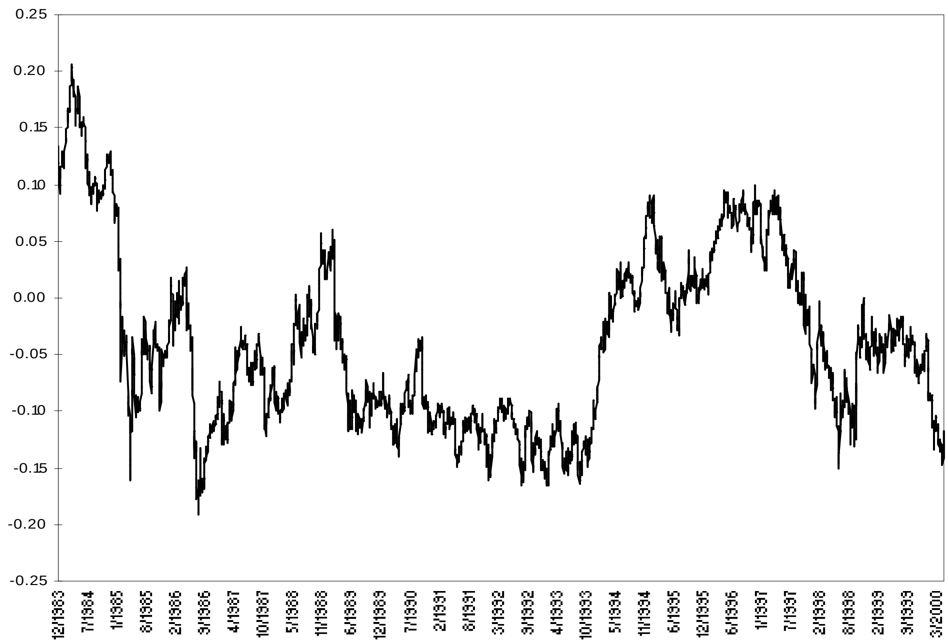
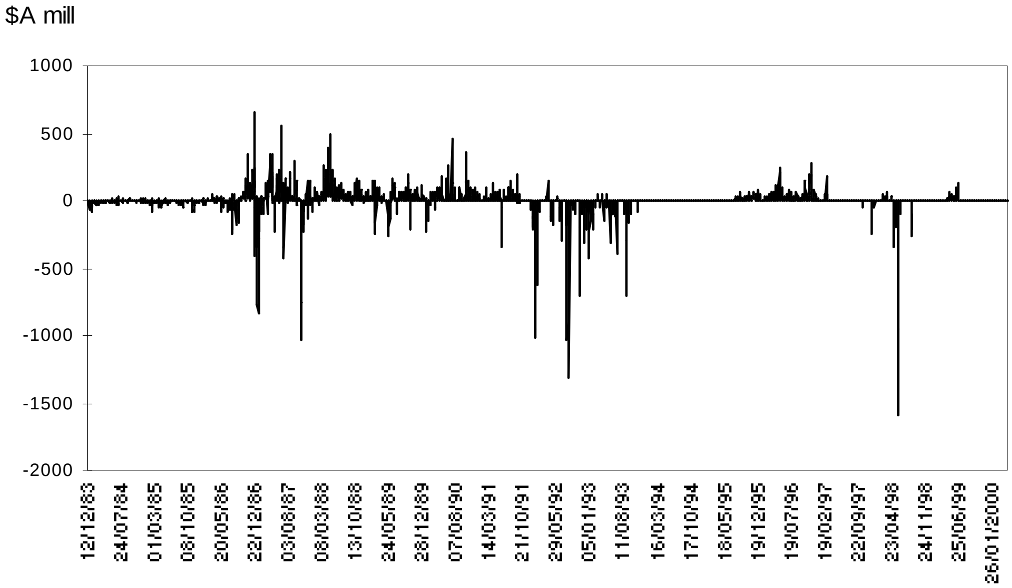


Figure 3: Deutsche Mark against the Australian Dollar Exchange Rate

Figure 4: Japanese Yen against the Australian Dollar Exchange Rate

Figure 5: Net Foreign Exchange Purchases by the Reserve Bank of Australia



Note: Negative values represent purchases of foreign exchange. Positive values represent the sales of foreign exchange.